Mechanick Dyalling

TEACHING

Any Man, though of an Ordinary Capacity and unlearned in the Mathematicks, To Draw a True

SUN-DIAL

ON ANY

Given Plane,

However Scituated: Only with the help of a straight RULER and a pair of COMPASSES; And without any Arithmetical Calculation.

The Third Edition.

By Joseph Moxon, *Fellow of the Royal Society, and Hydrographer to the King's most Excel. Majesty.*

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MECHANICK DYALLING.

Description of Dyalling.

DYalling originally is a *Mathematical Science*, attained by the Philosophical contemplation of the motion of the Sun, the motion of the Shadow, the Constitution of the Sphere, the Situation of Planes, and the consideration of Lines.

Explanation.

THE motion of the Sun is regular, it moving equal Space in equal Time; But the motion of the Shadow irregular in all parts of the Earth, unless under the two Poles, and that more or less according to the Constitution of the *Sphere* and Scituation of the *Plane*. And therefore Scientifick Dyalists by the Geometrick considerations of Lines, have found out Rules to mark out the irregular motion of the *Shadow* in all *Latitudes*, and on all *Planes*, to comply with the regular motion of the Sun. And these Rules of adjusting the motion of the Shadow to the motion of the Sun, may be called *Scientifick Dyalling*.

But though we may justly account *Dyalling* originally a *Science*, yet such hath been the Generosity of many of its studious Contemplators, that they have communicated their acquired Rules; whereby it is now become to many of the Ingenious no more difficult than an *Art*, and by many late Authors so Intituled: Nay more, by this small Treatise it will scarce be accounted more than a *Manual Operation*; for, though (hitherto) all the Authors I have met with seem to presuppose their Reader to understand *Geometry*, and the *projecting of the Sphere* already, or else endeavour in their Works to make him understand them, as if they were absolutely necessary to be known by every one that would make a Dyal, when as in truth, (the contemplative pains of others aforesaid considered) they are not; but indeed are only useful to those that would know the reason of *Dyalling*. Thus they do not only discourage young beginners, but also disappoint many Gentlemen and others, that would willingly either make them themselves, or set their Workmen about them, if they knew how to make them.

This little Piece I have therefore composed for the help of those who understand neither the *Projection of the Sphere*, or *Geometrical Operations*: Only, if they know how to draw a straight Line between two Points by the side of a Ruler, describe a Circle with a pair of Compasses, erect a Perpendicular, and draw one Line parallel to another, they may know how to draw a *Dyal* for any given *Plane*, whoever situated in a ſ Latitude.

But perhaps these two last little Tricks are not known to all new Beginners, therefore I shall shew them. First,

How to erect a Perpendicular. For Example, in Fig. 1.

Upon the Line A B you would erect a Perpendicular to the Point C: Place one Foot of your Compasses upon the point C, and open the other to what distance you please; For *Example*, to the point A, make there a mark; then keeping the first Foot still in C, turn the other Foot toward B, and make there another mark; then open your Compasses wider, suppose to the length A B, and placing one Foot in the point A, with the other Foot describe a small Arch over the point C, and removing the Foot of your Compasses to the point B, with the other Foot describe another small Arch, to cut the first Arch, as at D. Then lay your straight Ruler to the point where the two small Arches cut each other, and upon the point C, and by the side of the Ruler draw the Line C D, which shall be a Perpendicular to the Line A B.

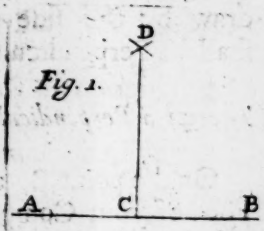


Fig. 1.

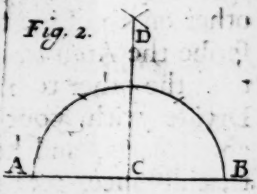


Fig. 2.

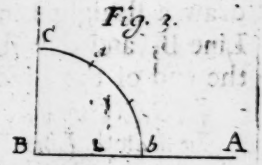


Fig. 3.

Fig. 4.

Another way with once opening the Compasses, as by Fig. 2.

Draw the Line A B, and place one Foot of your Compasses upon the point you would have the Perpendicular erected, as at the point C, and with the other foot describe the Semi-Circle A *a b* B, then placing one foot in B, extend the other foot to *b*, in

in the Semi-Circle; and keeping that Foot in *b*, extend the other Foot to D, and make there a ſmall Arch: Then remove one Foot of your Compaſſes to A, and extend the other Foot to *a* in the Semi-Circle, and keeping that Foot in *a*, extend the other to D, and make there another ſmall Arch, to cut the firſt ſmall Arch; and laying a ſtraight Ruler to the point where theſe two ſmall Arches cut each other, and upon the point C, draw by the ſide of the Ruler the Line C D, which ſhall be Perpendicular to the Line A B.

To erect a Perpendicular upon the end of a Line, as by Fig. 3.

On the point B, at one end of the Line A B, place one Foot of your Compaſſes in the point B, and extend the other on the Line towards A, as to *b*, and with it deſcribe the Arch *b a* C; then placing one Foot in *b*, extend the other to *a* in the Arch, and make there a mark; Divide with your Compaſſes the Arch *b a* into two equal parts, and keeping the Feet of your Compaſſes at that diſtance, meaſure in the Arch from *a* to C, then draw a ſtraight Line from the point C to the end of the Line B, and that ſtraight Line ſhall be Perpendicular to the end of the Line A B.

To draw a Line Parallel to another Line, as by Fig. 4.

Example. If you would draw a Line Parallel to the Line A B, open your Compaſſes to the diſtance you intend the Lines ſhall ſtand off each other, and placing one Foot ſucceſſively near each end, deſcribe with the other Foot the ſmall Arches C D; lay a ſtraight Ruler to the top of theſe Arches, and draw a Line by the ſide of it, and that Line ſhall be Parallel to the Line A B.

Definitions.

Definitions.

A *Dyal Plane* is that Flat whereon a *Dyal* is intended to be projected.

Of *Dyal Planes* ſome be *Direct*, others *Decliners*, others *Oblique*.

Of *Direct Planes* there are five ſorts.

1. The *Horizontal* whoſe Plane lies flat, and is parallel to the *Horizon*, beholding the *Zenith*.

2. The *South Erect*, whoſe Plane ſtands upright, and directly beholds the *South*.

3. The *North Erect*, whoſe Plane ſtands upright, and directly beholds the *North*.

4. The *Eaſt Erect*, whoſe Plane ſtands upright, and directly beholds the *Eaſt*.

5. The *Weſt Erect*, whoſe Plane ſtands upright, and directly beholds the *Weſt*.

Of *Decliners* there are infinite; and yet may be reduced into theſe two *Kinds*.

1. The *South Erect* Plane, declining more or leſs towards the *Eaſt* or *Weſt*.

2. The *North Erect* Plane, declining more or leſs towards the *Eaſt* or *Weſt*.

Of *Oblique Planes* ſome are *Direct*, other *Declining*; and are of four ſorts.

1. *Direct Inclining* Planes, which lean towards you, and lie directly in the *Eaſt*, *Weſt*, *North*, or *South* quarters of Heaven.

2. *Direct Reclining* Planes, which lean from you, and lie directly in the *Eaſt*, *Weſt*, *North*, or *South* quarters of Heaven.

3. *Inclining Declining* Planes, which lean towards you, but lie not directly in the *Eaſt*, *Weſt*, *North*, or *South* quar-

quarters of Heaven: But decline more or leſs from the the *North* or *South*, towards the *Eaſt* or *Weſt*.

4. *Reclining Declining* Planes, which lean from you, but lie not directly in the *Eaſt*, *Weſt*, *North*, or *South* quarters of Heaven: But Decline more or leſs from the *North* or *South*, towards the *Eaſt* or *Weſt*.

If the Scituation of the *Plane* be not given, you muſt ſeek it: For, there are ſeveral ways how to know theſe ſeveral kinds of *Planes* uſed among Artiſts; But the readieſt and eaſieſt is by an Inſtrument called a *Declinatory*, fitted to the variation of your Place: And if it be truly made, you may as ſafely rely upon it as any other.

OPERATIONI I.

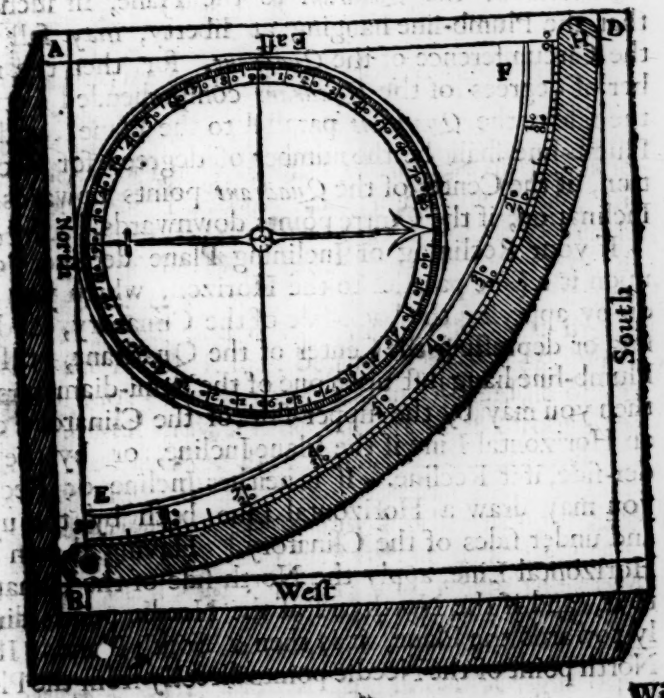
The Deſcription of the Clinatory.

THE Clinatory is made of a ſquare Board, as ABCD, of a good thickneſs, and the larger the better; between two of the ſides is deſcribed on the Center A, a *Quadrant* as EF divided into 90 equal parts or degrees, which are figured with 10, 20, 30 to 90; and then back again with the Complements of the ſame numbers to 90: Between the Limb and the two Semidiameters is made a round Box, into which a Magnetical Needle is fitted; and a Card of the Nautical Compaſs, divided into four Nineties, beginning their numbers at the *Eaſt*, *Weſt*, *North*, and *South* points of the Compaſs, from which points the oppoſite ſides of the Clinatory receives their Names of *Eaſt*, *Weſt*, *North* and *South*.

But, *Note*, That the North point of the Card muſt be placed ſo many degrees towards the *Eaſt* or *Weſt* ſides of the Clinatory, as the Needle varies from the true *North*

North point of the world, in the place where you make your Dyal; which your Workman that makes your Clinatory will know how to fit.

Upon the Center A, whereon the *Quadrant* was described, is fastened a Plumb-line, having a Plummet of Lead or Brass fastned to the end of it, which Plumb-line is of such length that the Plummet may fall just into the Grove G H, below the *Quadrant*, which is for that purpose made of such a depth, that the Plummet may ride freely within it, without stopping at the sides of it. See the Figure Annexed.



With this Clinatory you may examine the ſcituation of Planes. As if your Plane be Horizontal; it is direct: and then for the true ſcituating your Dyal, you have only the true North and South Line to find: which is done only by ſetting the Clinatory flat down upon the Plane, and turning it towards the right or left hand, till you can bring the North point of the Needle to hang juſt over the Flower-de-luce; for then if you draw a Line by either of the ſides parallel to the Needle, that Line ſhall be a North and South Line.

If your Plane either Recline or Incline, apply one of the ſides of your Clinatory parallel to one of the Semi-diameters of the *Quadrant* to the Plane, in ſuch ſort that the Plumb-line hanging at liberty, may fall upon the Circumference of the *Quadrant*, for then the number of degrees of the *Quadrant* comprehended between the ſide of the *Quadrant* parallel to the Plane, and the Plumb-line ſhall be the number of degrees for Reclination, if the Center of the *Quadrant* points upwards; or Inclination, if the Centre points downwards.

If your Reclining or Inclining Plane decline, draw upon it a Line parallel to the Horizon, which you may do by applying the back-ſide of the Clinatory, and raiſing or depreſſing the Center of the Quadrant, till the Plumb-line hang juſt upon one of the Semi-diameters, for then you may by the upper-ſide of the Clinatory draw an Horizontal Line if the Plane Incline, or by the under-ſide, if it Recline. If it neither Incline, or Recline, you may draw a Horizontal Line both by the upper and under ſides of the Clinatory. Having drawn the Horizontal Line, apply the North-ſide of the Clinatory to it, and if the North end of the Needle points directly towards the Plane, it is then a South [illegible]ne. If the North point of the Needle points directly from the Plane,

it is a *North* Plane: But if it points towards the *East*, it is an *East* Plane: If towards the *West*, a *West* Plane. If it do not point directly either East, West, North, or South, then so many degrees as the Needle declines from any of these four points to any of the other of these four points, so many degrees is the Declination of the Plane.

You may find a Meridian Line another way; thus, If the Sun shine just at Noon, hold up a Plumb-line so as the shadow of it may fall upon your Plane, and that shadow shall be a *Meridian Line*.

OPERAT. II.

To Describe a Dyal upon a Horizontal Plane.

First draw a North and South Line (which is called a *Meridian Line*) through the middle of the Plane; Thus, Set your *Declinatory* flat upon the Plane, and turn it too and fro till the Needle hang precisely over the *Meridian Line* of the *Declinatory*; then by the side of the *Declinatory* parallel to its *Meridian Line*, draw a straight Line on the Plane, and if that straight Line be in the middle of the Plane, it shall be the *Meridian Line*, without more ado: But if it be not in the middle of the Plane, you must draw a Line parallel to it through the middle of the Plane for the *Meridian Line*, or twelve a Clock line: And it shall be the *Meridian Line*, and also be the *Substilar Line*; then draw another straight Line through the middle of this Line, to cut it at right Angles for the VI a Clock Lines; and where these two Lines cut one another make your Centre, whereon describe a Circle on your *Plane* as large as you can, which by the *Meridian Line*, and the Line drawn at right An-

gles with it will be divided into four *Quadrants*; one of the *Quadrants* divide into 90 degrees thus, keeping your Compaſſes at the ſame width they were at when you deſcribed the *Quadrant*, place one Foot in the twelve a Clock Line, and extend the other in the *Quadrant*, and make in the *Quadrant* a mark with it; ſo ſhall you have the ſixtieth degree marked out: Then place one Foot of your Compaſſes in the ſix a Clock Line, and extend the other in the *Quadrant*, and make in the *Quadrant* another mark with it; ſo ſhall that *Quadrant* be divided into three equal parts, each of theſe three equal parts contains 30 Degrees: Then with your Compaſſes divide one of theſe three equal parts into three parts, and transfer that diſtance to the other two third parts of the *Quadrant*, ſo ſhall the whole *Quadrant* be divided into nine equal parts. Then divide one of theſe nine equal parts into two equal parts, and transfer that diſtance to the other eight equal parts, ſo ſhall the *Quadrant* be divided into Eighteen equal parts. Then divide one of theſe Eighteen equal parts into five equal parts, and transfer that diſtance to the other Seventeen equal parts, ſo ſhall the whole *Quadrant* be divided into 90 equal parts. Each of theſe 90 equal parts are called Degrees.

Note, That you may in ſmall *Quadrants* divide truer and with leſs trouble with Steel Dividers, (which open or cloſe with a Screw for that purpoſe,) then you can with Compaſſes.

In this *Quadrant* (thus divided) count from the *Subſtilar* or *Meridian Line* the Elevation of the *Pole*, that is, the number of Degrees that the *Pole* of the World is elevated above the *Horizon* of your Place, and draw a Line from the Center through that number of Degrees for the *Stilar Line*. Then on the *Subſtilar Line* chooſe

chooſe a point (where you pleaſe) and through that point draw a Line at right Angles to the *Subſtilar Line* as long as you can, for the Line of *Contingence*, and from that point in the *Subſtilar Line* meaſure the neareſt diſtance any part of the *Stiler Line* hath to that point; and keeping one Foot of your Compaſſes ſtill in that point, ſet off that diſtance in the *Subſtiler Line*, and at that diſtance deſcribe againſt the *Line* of *Contingence* a Semi-Circle, which divide from either ſide the *Meridian* or *Subſtiler Line* into ſix equal parts thus; Draw a line through the Center of this Semi-circle parallel to the *Line* of *Contingence*, which ſhall be the *Diametral Line*, and ſhall devide this Semi-Circle into two *Quadrants*; one on one ſide the *Subſtiler Line*, and the other *Quadrant* on the other ſide the *Subſtiler Line*: Then keeping your Compaſſes at the ſame diſtance they were at when you deſcribed the Semi-Circle, place one Foot firſt on one ſide the *Diametral Line* at the Interſection of it and the Semi-Circle, and then on the other ſide, at the Interſection of it and the Semi-Circle, and extend the other in the Semi-Circle, and make marks in the Semi-Circle on either ſide the *Subſtilar Line*; then place one Foot of your Compaſſes at the Interſection of the Semi-Circle and the *Subſtilar Line*, and turn the other Foot obout on either ſide the Semi-Circle and make marks in the Semi-Circle, ſo ſhall the Semi-Circle be divided into ſix equal parts; Divide one of theſe equal parts into two equal parts, and transfer that diſtance to the other five equal parts, ſo ſhall the whole Semi-Circle be divided into twelve equal parts. Theſe twelve Diviſions are to deſcribe the twelve Hours of the Day, between ſix a Clock in the Morning, and ſix a Clock at Night.

If you will have half Hours, you may divide each of theſe

theſe twelve into two equal parts, as before: If you will have Quarters you may divide each of theſe twenty four into two equal parts more, as before.

For thus proportioning the Diviſions in the Semi-Circle, you may proportion the Diviſions and Sub-diviſions of Hours upon the *Dyal Plane*; for a ſtraight Ruler laid upon each of theſe Diviſions, and on the Center of this Semi-Circle, ſhall ſhew on the *Line of Contingence* the ſeveral Diſtances of all the Hours and parts of Hours on the *Dyal Plane*. And ſtraight Lines drawn from the Center of the *Dyal Plane*, through the ſeveral Diviſions on the *Line of Contingence* ſhall be the ſeveral Hour Lines and parts on the *Dyal Plane*.

But an *Horizontal Dyal* in our Latitude will admit of four Hours more, *viz.* V, IV, in the Morning, and VII, VIII, in the Evening. Therefore in the Circle deſcribed on the Center of the *Dyal Plane* transfer the diſtance between VI and V, and VI and IV, on the other ſide the ſix a Clock Line; and transfer the Diſtances between VI and VII, and VI and VIII on the other ſide the oppoſite ſix a Clock Hour Line, and from the Center of the *Dyal Plane* draw Lines through thoſe transferred Diſtances for the Hour Lines before and after VI.

Then mark your Hour Lines with their reſpective numbers. The *Subſtilar Line* in this Dyal (as aforeſaid) is XII, from thence towards the right hand mark every ſucceſſive Hour Line with I, II, III, &c. and from XII towards the left hand with XI, X, IX, &c.

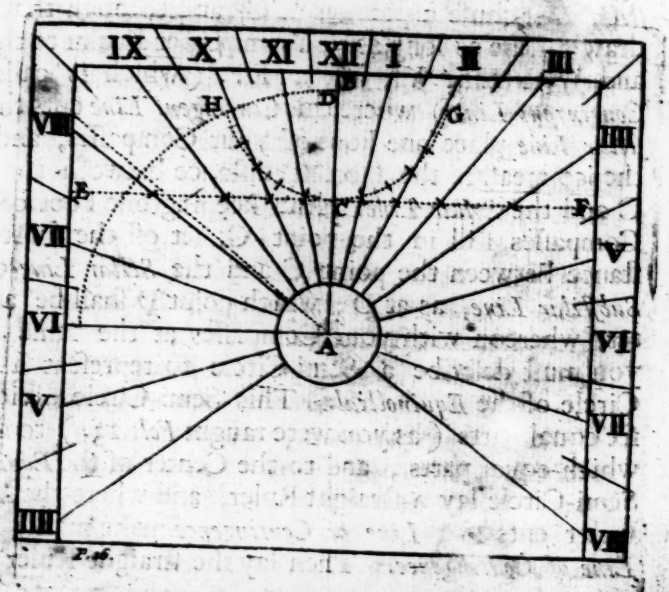
The *Stile* muſt be erected perpendicularly over the *Subſtilar Line*, ſo as to make an Angle with the *Dyal Plane* equal to the *Elevation* of the *Pole* of your Place.

Example

Example.

You would draw a Dyal upon a *Horizontal Plane* here at *London*; Firſt draw the *Meridian* (or North and South Line) as XII B, and croſs it in the middle with another Line at right Angles, as VI, VI, which is an Eaſt and Weſt Line; where theſe two Lines cut each other as at A, make the Center, whereon deſcribe the Semi-Circle B, VI VI; but one of the *Quadrants*, viz. the *Quadrant* from XII to VI, towards the right hand you muſt divide into 90 equal parts (as you were taught in *Fol.* 12.) and at 51½ degrees (which is *Londons* Latitude) make a mark, and laying a ſtraight Ruler to the Center of the *Plane*, and to this mark draw a Line by the ſide of it for the *Stilar Line*. Then on the *Subſtilar Line* chuſe a point as at C, and through that point draw a Line as long as you can perpendicular to the Eaſt and Weſt Line VI, VI, as E F, (which is called the *Contingent Line*) where this *Contingent Line* cuts the *Subſtilar Line* place one Foot of your Compaſſes, and from thence meaſure the ſhorteſt diſtance between the point C and the *Stilar Line*. And keeping one Foot of your Compaſſes ſtill in the point C, ſet off the ſhorteſt diſtance between the point C and the *Stilar Line* on the *Subſtilar Line*, as at D; which point D ſhall be a Center, whereon with your Compaſſes at the ſame width you muſt deſcribe a Semi-Circle to repreſent a Semi-Circle of the *Equinoctial*. This Semi-Circle divide into ſix equal parts (as you were taught *Fol.* 13.) to each of which equal parts, and to the Center of the *Equinoctial* Semi-Circle lay a ſtraight Ruler, and where the ſtraight Ruler cuts the *Line of Contingence* make marks in the *Line of Contingence*. Then lay the ſtraight Ruler to the

Semi-Circle of the *Dyal Plane*, and to each of the marks in the *Line of Contingence*, and by the ſide of it draw twelve ſtraight Lines for the twelve Fore and Afternoon Hour Lines, *viz.* from VI in the Morning to VI in the Evening. Then in the *Quadrant* V I B, meaſure the diſtance between the VI a Clock Hour Line, and the V a Clock Hour Line, and transfer the ſame diſtances from the VI a Clock Line to VII, and V on both ſides the VI a Clock Hour Lines, and through thoſe diſtances draw from the Center of the Plane the VII and V a Clock Hour Lines, and meaſure the diſtance between the VI a Clock Hour Line and the IV a Clock Hour Line, and transfer the ſame diſtance from the VI a Clock Line to VIII and IV, and through thoſe diſtances draw from the Center of the Plane the VIII a Clock and IV a Clock Hour Lines.



If you will have the half Hours and quarter Hours, or any other diviſion of Hours, you muſt divide each ſix diviſions of the *Equinoctial* into ſo many parts as you intend, and by a ſtraight Ruler laid to the Center of the *Equinoctial*, and thoſe diviſions in the *Equinoctial* Circle make marks in the *Line of Contingence*, as you did before for the whole Hour Lines: and Lines drawn from the Center of the Plane through thoſe marks ſhall be the ſub-diviſions of the Hours: But you muſt remember to make all ſub-diviſions ſhort Lines, and near the verge of the *Dyal Plane*, that you may the eaſier diſtinguiſh between the whole Hours and the parts of Hours; as you may ſee in the Figure.

Having drawn the Hour-Lines, ſet the number of each Hour Line under it, as you ſee in the Figure.

Laſt of all fit a Triangular Iron, whoſe angular point being laid to the Center of the *Dyal Plane*, one ſide muſt agree with the *Subſtilar Line*, and its other ſide with the *Stilar Line*; ſo is the *Stile* made. And this *Stile* you muſt erect perpendicularly over the *Subſtilar Line* on the *Dyal Plane*, and there fix it. Then is your *Dyal* finiſhed.

OPERAT. III.

To deſcribe an Erect Direct South-Dyal.

YOU may know an *Erect Direct South-Plane*, by applying the North-ſide of the *Declinatory* to it; For then, if the North-end of the Needle hang directly over the North-point of the Card in the bottom of the Box, it is a *South-Plane*; but if it hang not directly over the North-point of the Card, it is not a *Direct South-Plane*, but *Declines* either Eaſt or Weſt, and that

contrary to the pointing of the Needle Eaſterly or VVeſterly, from the North-point of the Card: for, if the North-point of the Needle points Eaſterly, the *Plane Declines* from the South towards the VVeſt: if it point VVeſterly, the *Plane Declines* from the South towards the Eaſt.

You may know, if the *Plane* be truly *Erect* or upright, by applying one of the ſides A D or A B to it; for then by holding the Center A upwards, ſo as the Plumb-line play free in the Groove, if the Line falls upon 0, or 90, the *Plane* is upright; but, if it hang upon any of the intermediate Degrees, it is not upright, but *Inclines* or *Reclines*.

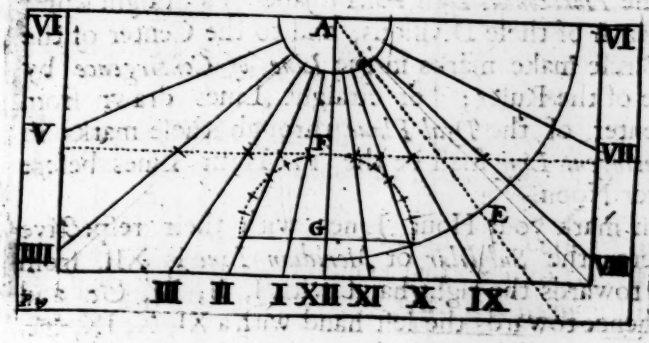
If you find it incline, apply the ſide A B to it, and ſee what number of Degrees the Plumb-line falls on, for that number of Degrees counted from the ſaid A B, is the number of Degrees of *Inclination*.

If you find the *Plane Reclines*, apply the ſide A D to it, and ſee what number of Degrees the Plumb-line falls on, for that number of Degrees counted from the ſide A D, is the number of Degrees of *Reclination*.

Theſe Rules being well underſtood, may ſerve you to find the ſcituation of all other ſorts of Planes.

But for the making a *Dyal* on this *Plane*, you muſt firſt draw a *Meridian Line* through the middle of the *Plane*, by applying a Plumb-line to the middle of it, till the Plumbet hang quietly before it: for then, if the Plumb-line be blacked (for a white Ground, or chalked for a dark Ground) and ſtrained as Carpenters do their Lines, you may with one ſtroke of the ſtring on the *Plane*, deſcribe the *Meridian Line*, as A XII. This *Meridian* is alſo the *Subſtilar Line*.

Then



Then on the top of this *Meridian Line*, as at A, draw another Line athwart it, to cut it at right Angles, as VI, VI. for an East and West Line. At the meeting of these two Lines at the top, make your Center, whereon describe a Semi-Circle on your *Plane*, as large as you can, which by the *Meridian Line* and the East and West Line, will be divided into two *Quadrants*. One of these *Quadrants* divide into 90 Degrees (as you were taught *Fol.* 12.) and from the *Substilar Line* count the Complement of the *Poles Elevation*, which (here at *London* where the *Pole* is elevated 51½ Degrees, its Complement to 90) is 38½ Degrees, and make there a mark, as at E. Then on the *Substilar Line* chuse a point (where you please) as at F, for the *Line of Contingence* to pass through; which *Line of Contingence* draw as long as you can, so as it may cut the *Substilar Line* at right Angles, and from the point F in the *Substilar Line*, measure the shortest distance between it and the *Stilar Line*, and keeping one Foot of your Compasses still in the point F, transfer that distance into the *Substilar Line*, as at G, then on the point G describe a Semi-Circle of the *Equinoctial* against the *Line of Contingence*, which Semi-Circle divide into

twelve equal parts, (as you were taught by the *Example* in the *Horizontal Dyal*, Fol. 13.) and by a ſtraight Ruler laid to each of theſe Diviſions, and to the Center of the Semi-Circle make marks in the *Line of Contingence* by the ſide of the Ruler; for ſtraight Lines drawn from the Center of the *Dyal Plane* through theſe marks in the *Contingent Line* ſhall be the 12 Hour Lines before and after Noon.

Then mark your Hour Lines with their reſpective Numbers; the *Subſtilar* or *Meridian Line* is XII, from thence towards the right hand with I, II, III, &c. and from thence towards the left hand with a XI, X, IX, &c.

The *Stile* muſt be erected perpendicular over the *Subſtilar Line*, ſo as to make an Angle with the *Dyal Plane* equal to the Complement of the *Poles Elevation*, viz. 38½ Degrees.

OPERAT. IV.

To make an Erect Direct North Dyal.

THE *Erect Direct* North Dyal, Stile and all, is made by the ſame Rules, changing upwards for downwards, and the left ſide for the right, the *Erect Direct South Dyal* is made; for if the *Erect Direct South Dyal* be drawn on any tranſparent Plane, as on Glaſs, Horn, or an oyled Paper, and the *Horizontal Line* VI, VI, turned downwards, and the Line VII mark't with V, the Line VIII with IIII, the Line V with VII, and the Line IIII with VIII, then have you of it a *North Erect Direct Dyal*.

All the other Hour Lines in this Dyal are uſeleſs, becauſe the Sun in our Latitude ſhines on a North face the longeſt Day only before VI in the Morning, and after VI at Night.

OPERAT.

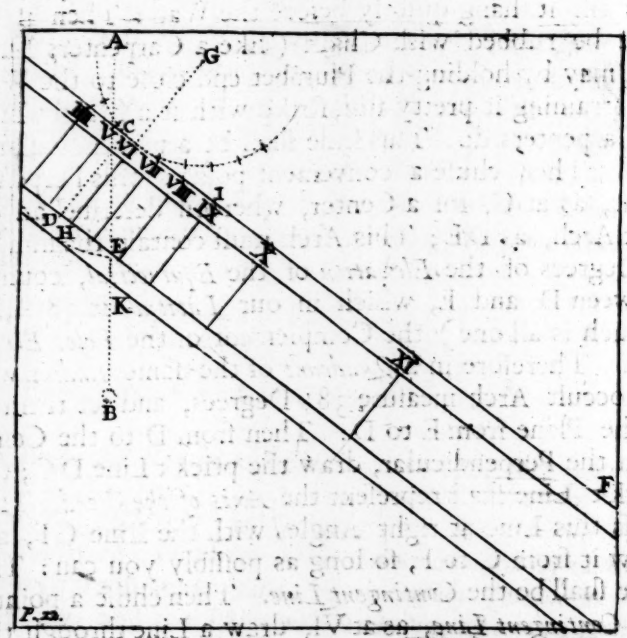
OPERAT. V.

To describe an Erect Direct East Dyal.

HAving a Plumb-line a little above the Place on the Wall where you intend to make your Dyal, and wait till it hang quietly before the Wall: Then if the Line be rubbed with Chalk (like a Carpenters Line) you may by holding the Plumbet end close to the Wall, and straining it pretty stiff, strike with it a straight Line, as Carpenters do: This Line shall be a perpendicular, as A B. Then chuse a convenient point in this Perpendicular, as at C, for a Center, whereon describe an occult Arch, as D E; This Arch must contain the number of Degrees of the *Elevation* of the *Equinoctial*, counted between D and E, which in our *Latitude* is 38 ½, or (which is all one) the Complement of the *Poles Elevation*. Therefore in a *Quadrant* of the same *Radius* with the occult Arch measure 38½ Degrees, and set them off in the Plane from E to D: Then from D to the Center C in the Perpendicular, draw the prick't Line D C; this prick't Line shall represent the *Axis of the Word*. Then cross this Line at right Angles with the Line C F, and draw it from C to F, so long as possibly you can: This Line shall be the *Contingent Line*. Then chuse a point in this *Contingent Line*, as at VI, draw a Line through that point at right Angles for the *Substilar Line*, as G VI H for the *Substilar Line*; then open your Compasses to a convenient width, (as to VI G) and pitching one Foot in the point G, with the other Foot describe a Semi-Circle of the *Equinoctial* against the *Line of Contingence*, which Semi-Circle divide from VI both ways into six equal parts, as you were taught by the *Example* in the

Horizontal

zontal Dyal; and laying a ſtraight Ruler on the Center of this Semi-Circle of the *Equinoctial*, and to each of thoſe equal parts mark on the *Contingent Line* where the Ruler cuts it, for thoſe marks ſhall be the ſeveral points from whence Lines drawn parallel to the Line C D ſhall be the reſpective Hour Lines.



The reaſon why the *Contingent Line* is drawn from VI to F, ſo much longer than from VI to G is, becauſe the Hour Lines from VI towards XII are more in number towards Noon, than they are from backward towards III, for this Dyal will only ſhew the Hours

from

from a little before IV in the Morning to almoſt Noon. For juſt at Noon the Shadow goes off the Plane; as you may ſee, if you apply a ſtraight Ruler to the Center of the Equinoctial Semi-circle G, and lay it to the point 12 in the Semi-Circle; for the ſtraight Ruler will then never cut the *Line of Contingence*, becauſe the *Line of Contingence* is parallel to the line G XII on the Equinoctial Circle, and Lines parallel, though continued to never ſo great a length, never meet.

To theſe *Hour Lines*, ſet Figures as may be ſeen in the Scheme.

The *Stile* LK of this Dyal, as well as of all others, muſt ſtand parallel to the *Axis of the World*; and alſo parallel to the Face of the *Plane*, and parallel to all the *Hour Lines*, and ſtand directly over the *Subſtilar* or VI a Clock *Hour Line*, and that ſo high as is the diſtance of the Center of the Equinoctial Semi-circle from the *Contingent Line*.

OPERAT. VI.

To deſcribe a Dyal *on an* Erect Direct VVeſt-Plane.

AN Erect Direct *Weſt-Dyal*, is the ſame in all reſpects with an Erect Direct Eaſt-Dyal; only as the Eaſt-Dyal ſhews the Forenoon Hours, ſo the VVeſt ſhews the Afternoon Hours.

Thus, if you ſhould draw the *Eaſt-Dyal* on any tranſparent *Plane*, as on Glaſs, Horn, or oyled Paper, on the one ſide will appear an *Eaſt-Dyal*, on the other ſide a *VVeſt*; only the numbers to the *Hour Lines* (as was ſaid before in the *North-Dyal*,) muſt be changed; for that which in the *Eaſt-Dyal* is XI, in the *VVeſt* muſt be I; that which in the *Eaſt-Dyal* is X, in the *VVeſt*

muſt

must be II; that which in the *East Dyal* is IX, in the *West* must be III, &c. The Stile is the same.

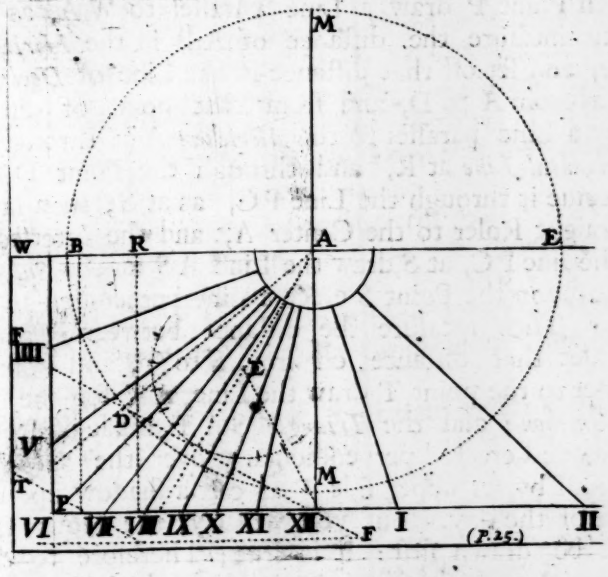
OPERAT. VII.

To describe a Dyal on an Erect North, *or* Erect South Plane Declining *Eastwards or Westwards.*

THese four Dyals, *viz.* the *Erect North Declining Eastwards*, the *Erect North Declining Westwards*, the *Erect South Declining Eastwards*, and the *Erect South Declining Westwards*, are all projected by the same Rules; and therefore are in effect but one Dyal differently placed, as you shall see hereafter.

First draw on your *Plane* a straight Line to represent the *Horizon* of your place, and mark one end of it W for *West*, and the other end E for *East*. Chuse a point in this *Horizontal* Line for a Center, as at A, whereon you may describe a Circle to comprehend all these four *Dyals:* Draw a Line as MAM perpendicular to the *Horizontal Line* WE, through the Center A for a *Meridian Line*, and on that Center describe a Circle, which by the two Lines WAE, and MAM will be divided into four *Quadrants*, which will comprehend the four *Dyals* aforesaid; for if it be a *North declining West* you are to draw, the upper *Quadrant* to the left hand serves your purpose: If a *South declining West*, the same Lines continued through the Center A into the lower *Quadrant* to the right Hand serves your turn; if a *North Declining East*, the upper *Quadrant* to the right hand serves your turn; or if a *South declining East*, the same Lines continued through the Center A into the lower *Quadrant* to the left hand serves your turn; and you must draw the *Declination, Complement of the Poles Altitude, Substile, Stile* and

and *Hour Lines* in it; but the *Hour Lines* muſt be differently marked as you ſhall ſee hereafter. I ſhall only give you an Example of one of theſe Dyals, *viz.* A *South Declining Eaſt.*



We will ſuppoſe you are to draw a *Dyal* that *declines* from the *South* 50 Degrees towards the *Eaſt*; here being but one *Dyal*, you need deſcribe but one *Quadrant* of a Circle. Set off in the lower *Quadrant* W A M 50 degrees from the *Meridian Line* M towards W, and from the Center A draw a ſtraight Line through that mark in the *Quadrant* as D A, which may be called the *Line of Declination*; then ſet off from the *Meridian Line* the *Complement* of the *Poles Elevation*, which in our Latitude is 38½ degrees, and there draw another Line from the Center as A P, which we will call the *Polar Line.*

Then take in the *Horizontal Line* a convenient portion of the *Quadrant*, as A B, and from the point B draw a Line parallel to the *Meridian Line* A M, and continue that Line till it interſect the *Polar Line*, as at P, from which Point P draw a Line parallel to W A, as P C: Then meaſure the diſtance of A B in the *Horizontal Line*, and ſet off that diſtance in the Line of *Declination*, as from A to D, and from that point of diſtance draw a Line parallel to the *Meridian* A M through the *Horizontal Line* at R, and through the Point D, and continue it through the Line P C, as at S; then laying a ſtraight Ruler to the Center A, and the Interſection of the line P C, at S, draw the Line A S for the *Subſtile*: Then upon the Point S erect a Line perpendicularly as S T; Then meaſure the diſtance between R and D, and ſet that diſtance off from S to T, and from the Center to the point T draw the Line A T for the *Stile* or *Gnomon*; and the *Triangle* S A T made of Iron or Braſs, and erected perpendicularly over the *Subſtile* S A, ſhall by its upper ſide T A, caſt a ſhadow upon the Hour of the day. But you will ſay, the Hour Lines muſt be drawn firſt: It is true; Therefore to draw them you muſt chuſe a point in the *Subſtile Line* where you think good, and through it draw the Line F F as long as you can for the *Line of Contingence*; then with your Compaſſes take the ſhorteſt diſtance between this point and the *Stile*, and transfer that diſtance below the *Line of Contingence* on the *Subſtile* as at Æ, and with your Compaſſes at that diſtance deſcribe on the Center Æ a Circle to repreſent the *Equinoctial*; then (as you were taught in the Example of the *Horizontal Dyal*) divide the Semi-Circle of the *Equinoctial* into twelve equal parts, beginning at the point in the *Equinoctial Circle*, where a ſtraight Line drawn from the Center of it to the

the Interſection of the Line of *Contingence* with the Meridian Line cuts the *Equinoctial* Line, as here at the Point G; then lay a ſtraight Ruler to the Center of the *Equinoctial Circle*, and to every one of the Diviſions in the Semicircle, and mark where the ſtraight Ruler cuts the *Contingent Line*; for ſtraight Lines drawn from the Center A of the Dyal to thoſe ſeveral marks on the *Contingent Line*, ſhall be the *Hour Lines*; and muſt be numbred from the Noon Line or *Meridian* A M backwards, as XII, XI, X, IX, *&c.* towards the left hand. So is your Dyal finiſhed.

This Dyal drawn on any tranſparent matter, as Horn, Glaſs, or an oyled Paper, ſhall on the other ſide the tranſparent matter become a *South Declining Weſt* (*Stile* and all) but then the I a Clock Hour Line muſt be marked II, the XII, XII, the XI a Clock Hour Line, I, X, II, IX, III, *&c.*

If you project it anew, you muſt deſcribe the *Quadrant* M W on the other ſide the *Meridian Line*, on the Center A from M to E, and then count, (as before) the *Declination*, *Altitude* of the *Pole*, *Subſtile*, and *Stile* in the *Quadrant*, beginning at M towards E, and work in all reſpects as with the *South Declining Eaſt*; only number this *South Declinging Weſt* as in the foregoing Paragraph.

If you project a *North Declining Eaſt*, you muſt deſcribe the *Quadrant* above the *Horizontal Line* from M upwards, towards E on your right hand, and count (as before) the *Declination*, *Altitude*, *Complement* of the *Pole*, *Subſtile* and *Stile* from the *Meridian Line*, and work as with the *South Declining Eaſt*: It muſt be numbred from the *Meridian* Line M towards the right hand with XI, X, IX, VIII, *&c.*

If this *Dyal* were drawn on tranſparent matter, the other ſide would ſhew a *North Declining Weſt:* But if you will project it anew, you muſt deſcribe the *Quadrant* above the *Horizontal Line*, from M upwards towards W, and count from the *Meridian Line* A M the *Declination*, *Complement*, *Altitude of the Pole*, *Subſtile* and *Stile*, and work with them (in all reſpects) as with the *South Declining Eaſt*; but then the XI a Clock Hour Line muſt be marked I, the X, II; the IX, III, *&c.*

OPERAT. VIII.

To draw a Dyal on an Eaſt *or* Weſt Plane Reclining, *or* Inclining.

DRraw a ſtraight Line parallel to the *Horizon*, to repreſent the *Meridian*, or XII a Clock Line, and mark one end N, the other S; chuſe a point in this Line, as at A for a Center: Then if your Plane be an *Eaſt*, or a *Weſt Incliner*, let fall a Perpendicular upon this Center, (that is, the Perpendicular muſt ſtand above the Meridian Line N S) as A E, and upon the Center A deſcribe a Semi-Circle above the Meridian Line N S;) But if your Plane be an Eaſt Incliner, or a Weſt Recliner, let fall a Perpendicular from the Center A under the Meridian Line, and upon the Center A deſcribe a Semi-Circle under the *Meridian Line*. If your Plane be a *Weſt Incliner*, work (as ſhall be taught) in the *Quadrant* on the left hand above the *Meridian* Line. If an Eaſt Recliner, in the *Quadrant* on the right hand above the Meridian Line. If it be a Weſt Recliner, work in the *Quadrant* on the left hand under the *Meridian*. If an Eaſt Incliner, in the Quadrant under the Meridian Line the right hand.

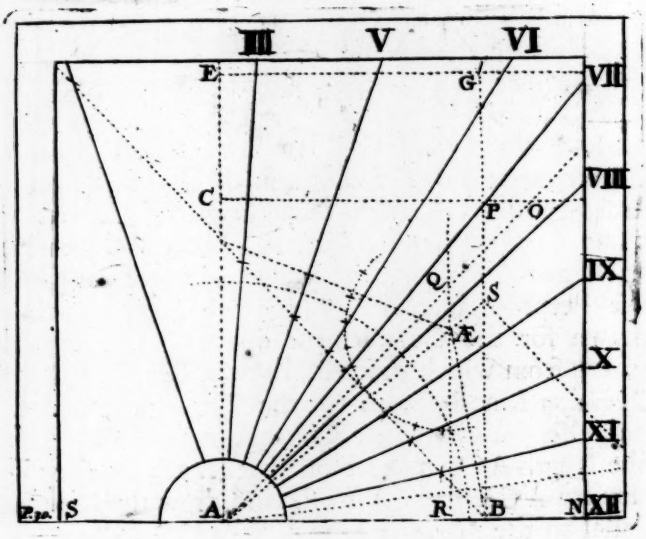
For

For Example, *An Eaſt Dyal Reclining* 45 *Decrees.*

You would draw a *Dyal* on an *Eaſt Plane Reclining* 45 Degrees: Therefore in the *Quadrant* on the right hand above the *Meridian* Line, ſet off from the Perpendicular A E 45 Degrees on the *Quadrant*, for the Reclination of the *Plane*; and ſet off alſo in the *Quadrant* 38½ Degrees from the Perpendicular for the *Complement of the Poles Elevation*, and at theſe ſettings off make marks in the *Quadrant*: Then lay a ſtraight Ruler to the Center A, and to the marks in the *Quadrant*, and draw ſtraight Lines through them from the Center. Then chuſe in the *Meridian* Line N S a convenient point, as at B, and through that point draw a Line parallel to the Perpendicular A E, which will interſect the Line drawn for the Complement of the *Poles Elevation* A P in P; from which point P, draw a Line parallel to the *Meridian* Line N S, to cut the Perpendicular A E in C, and alſo the Line of Obliquity A O in O. Then meaſure the length A O, and ſet off that length in the Perpendicular A C E from A to E, and draw the Line E G parallel to the *Meridian* Line N S, which will cut the Line B P prolonged in G. Meaſure alſo the length of C O, and ſet that length off from A to Q on the Line of Obliquity A O, and draw the Line Q R parallel to the Perpendicular A C E. Then meaſure the diſtance of A R, and upon the Line G P B, ſet it off from G to S; and laying a ſtreight Ruler to the point S and the Center A, draw by the ſide of it the Line A S, for the *Subſtile* Line. Then meaſure the length of Q R, and from S raiſe a Perpendicular, and in that Perpendicular, ſet that length off from S to T; and laying a ſtraight Ruler to the Center A and the point T, draw the Line:

A T

A T for the *Stilar* Line, which *Stilar* Line being perpendicular erected over the *Subſtilar* Line A S, will ſtand parallel to the *Axis of the World*, and caſt its ſhadow on the Hour of the Day.



To draw the Hour Lines on this Plane, you muſt (as you have ſeveral times before been directed) chuſe a point in the *Subſtilar* Line, and through that point draw at right Angles with the *Subſtilar* Line the Line of *Contingence* ſo long as you can: Then meaſure the ſhorteſt diſtance between that Point and the *Stilar* Line, and transfer that diſtance below the Line of *Contingence* in the *Subſtilar* Line, as at Æ, and with your Compaſſes

paſſes at that diſtance, deſcribe againſt the Line of Contingence the Equinoctial Circle; then divide the Semi-Circle of the *Equinoctial* next the Line of *Contingence* into twelve equal parts, as you have formerly been taught, beginning at the Point in the *Equinoctial Circle*, where a ſtraight Line drawn from the Center of it to the Interſection of the Line of *Contingence* with the *Meridian* Line N S cuts the *Equinoctial Circle*, as here at the point D: Then lay a ſtraight Ruler to the Center of the *Equinoctial* Circle, and to every one of the Diviſions in the *Equinoctial* Semi-Circle, and mark where the ſtraight Ruler cuts the *Contingent* Line; for ſtraight Lines drawn from the Center A of the Dyal, through theſe ſeveral marks in the *Contingent* Line ſhall be the Hour Lines, and muſt be numbred from the *Meridian* or Noon-Line N S which is the XII a Clock Line upwards, with XI, X, IX, VIII, *&c.* The Center of this Dyal muſt ſtand downward.

If this Dyal were turned with its Center upwards, it would ſhew a *Weſt Inclining* 45 degrees, only the numbers to the Hour Lines muſt be changed; for to XI you muſt ſet I, to X, II, to IX, III, *&c.* and the *Subſtile* over which the Stile muſt ſtand, muſt be placed in the Semi-Circle (at firſt deſcribed) as much to the right hand the perpendicular A E, as it doth on the left hand.

If this Dyal were drawn on Glaſs, Horn, or an oyled Paper, and you turn the *Meridian* Line N S upwards, the back ſide ſhall be an *Eaſt Inclining* 45 degrees, and the Hour Lines muſt be numbred as they are on the *Eaſt Reclining*; But the Subſtile over which the Stile muſt ſtand, muſt be placed in the Semi-Circle (at firſt deſcribed) as much to the left hand the perpendicular A E, as it is on the oyled Paper to the right hand.

If

If you turn the *Meridian* Line N S downwards, the backside shall be a *West Recliner* 45 Degrees, and the Hour Lines must be numbred from the XII a Clock line upwards, with I, II, III, &c.

You must Note that all the Hour-lines of the Day will not be described in this single *Quadrant*, nor does the *Quadrant* at all relate to the Hour-lines; but is described only for setting off the *Complement* of the *Poles Elevation* and *Reclination* of the *Plane*, that by working (as hath been shewn) you may find the place of the Substilar line, and the Angle the Stile makes with it; for having the Substilar line, you know how to draw the line of *Contingence*, and to describe the *Equinoctial* Circle, by which all the Hours are described on the *Plane*.

To draw a Dyal *on a* Direct South *or* North Plane Inclining *or* Reclining.

Direct Reclining or *Inclining* Dyals are the same with Erect Direct Dyals that are made for the Latitude of some other Places; the Latitude of which Places are either more than the Latitude of your place, if the Plane *Recline*, or less, if the Plane *Incline*; and that in such a proportion as the Arch of *Reclination* or *Inclination* is.

Thus a Direct South Dyal *Reclining* 10 degrees in *London*'s Latitude, (*viz.* 51 ½ degrees) is an Erect Direct South Dyal made for the Latitude of 61 ½ degrees. And a Direct South Dyal *Inclining* 10 in the Latitude of 51 ½ is an *Erect Direct South* Dyal in the *Latitude* of 41 ½ degrees, and is to be made according to the Direction given in *Operat.* III.

OPERAT.

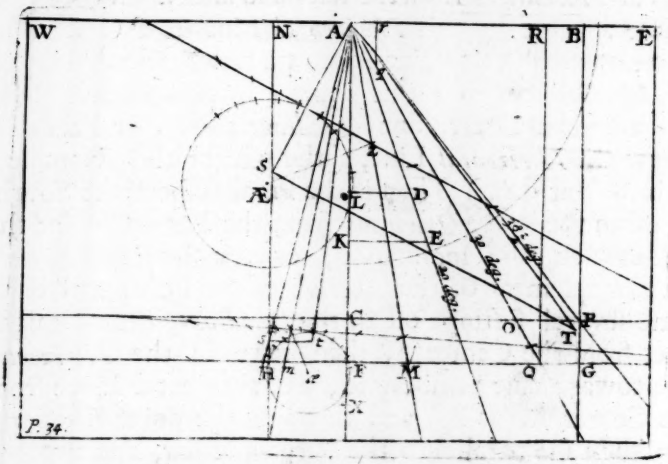
OPERAT. IX.

To draw a Dyal *on a* South *or* North Inclining Declining, *or* Reclining Declining Plane.

THeſe four ſorts of Dyals, *viz.* the South Inclining Declining, and South Reclining Declining, and North Inclining Declining, and South Reclining Declining, are all projected by the ſame Rules; and therefore are in effect but one Dyal differently placed, as you ſhall ſee hereafter.

Firſt draw on your Plane a ſtraight Line parallel to the *Horizon*, and mark one end W for *Weſt*, and the other E for *Eaſt*. On South Incliners and Recliners, E on the right hand, and W on the left; on North Incliners and Recliners E on the left hand and W on the right. Chuſe a point in this *Horizontal* Line for a Center, as at A; through this point A draw a line Perpendicular to the *Horizon*, and on this point (as on a Center) deſcribe a Semi-Circle, one *Quadrant* above, and another below the *Horizontal* Line, (though for this Example I deſcribe but one.) Then if the Plane reſpect the South, ſet off in the lower *Quadrant* from the Perpendicular the Declination, the Inclination, or the Reclination, and the Complement of the *Altitude* of the Pole; and thro' theſe ſeveral ſettings off in the *Quadrant*, draw ſtraight lines from the Center A, then take in the *Horizontal* line toward the Semi-circle, a convenient diſtance from the Center A, as B, and through the point B draw a ſtraight Line parallel to the Perpendicular, and prolong it through the Polar line, as BP; through the point P, draw a line parallel to the *Horizontal* line, as PC; this line will cut the line of *Obliquity* in the point O, then meaſure the diſtance of A O, and ſet off that diſtance on

the Perpendicular from A to F, and through the point F draw a ſtraight line parallel to the *Horizontal* line, as F G, for the *Horizontal* Interſection. Then meaſure the diſtance of C O, and ſet off that diſtance on the Perperpendicular from A to L; from the point L, draw the line L D parallel to the *Horizontal* line, to cut the line of *Declination* in the point D. Then meaſure the diſtance of A B, and ſet of that diſtance in the Line of Declination from A to E; and from the point E, draw a ſtraight line parallel to the *Horizontal* line W E, to cut the Perpendicular in the point K. Meaſure the diſtance of E K, and ſet off that diſtance on the other ſide the Perpendicular in the *Horizontal* Interſection, from F to H, and from the point H draw H N parallel to the Perpendicular to cut the *Horizontal* line in the point N.



Then to find the *Meridian* line, *Subſtile* and *Stile*, do thus. If your *Plane* be a *Southern Incliner*, or a *Northern Recliner*, meaſure the diſtance of L D, and ſet off that

that diſtance in the *Horizontal* Interſection from F to M, and through the point M draw the line A M for the *Meridian* line. Then add the diſtance of A L to A K, thus: Meaſure the diſtance of A L, and place one Foot of your Compaſſes in the point K in the Perpendicular line, and extend the other to X, and meaſuring the diſtance of A X, ſet it off in the line of *Obliquity* from A to Q; and from the point Q draw the line Q R parallel to the Perpendicular, and cutting the *Horizontal* line in the point R. Then meaſure the diſtance of A R, and ſet off that diſtance from H in the *Horizontal* Interſection to S on the line H N, and to the point S draw the line A S for the *Subſtile.* Then meaſure the diſtance of Q R, and ſet off that diſtance perpendicularly from the point S to T; and laſtly, from the point A, draw the ſtraight line A T for the *Stilar* line, which *Stilar* line being perpendicularly erected over the *Subſtilar* line A S, will ſtand parallel to the *Axis of the World,* and caſt its ſhaddow on the Hour of the Day.

But if the Plane be a *Southern Recliner,* or *Northern Incliner,* meaſure (as before) the diſtance of L D, and (as before you were directed) to ſet it off from F in the *Horizontal* Interſection on the right hand the perpendicular line: So now, ſet that diſtance from F to *m* in the *Horizontal* Interſection on the left hand in the Perpendicular line, and draw the line A *m* for the *Meridian* Line. Then as before you were directed, to add A L to A K; So now, ſubſtract the diſtance of A L from A K, and the remainder will be L K: Set therefore the diſtance of L K from A to *q* in the ſame line of *Obliquity,* and from the point *q* draw the line *q r* parallel to the perpendicular. Meaſure then the diſtance of A *r*, and ſet off that diſtance in the line H N, from H to *s* for the *Subſtilar* line; then erect on the point *s* a perpendicular,

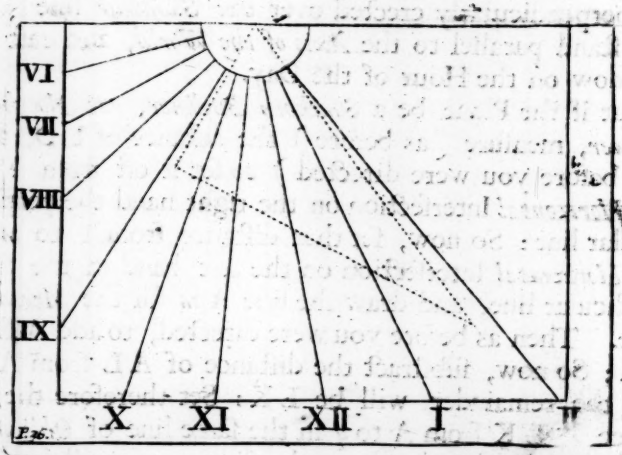
and on that Perpendicular ſet off from *s* to *t* the diſtance of *q r*: And laſtly, from A draw the line A *t* for the *Stilar Line*.

If K falls upon L the *Plane* is parallel to the *Axis of the World*, and the Dyal drawn upon it will have no Center; But *s* will fall upon H, and A H (or A *s*) will be the *Subſtile*.

I ſhall give you two Examples of theſe Rules: One of a Dyal with a Center, and the other of a Dyal without a Center. And firſt,

OPERAT. X.

How to draw a Dyal *with a Center*, Declining 20 *Degrees, and* Inclining 30 *Degrees.*



HAving by the foregoing Precepts of the laſt *Operat.* found the *Subſtile*, *Stile*, and *Meridian*, you muſt (as you have often been directed) chuſe a point in the *Subſtilar*

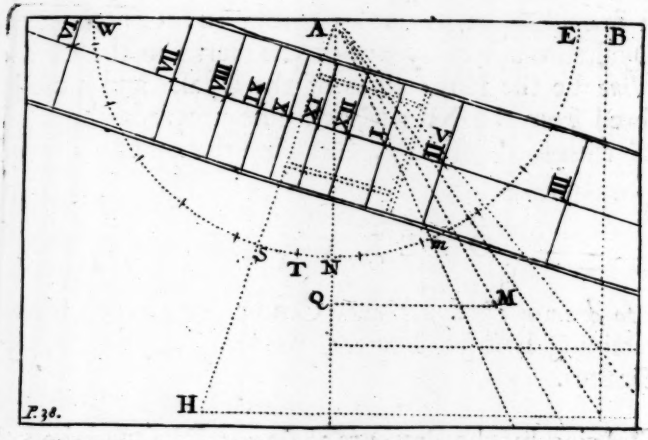
lar line, through which at right Angles to the *Subſtilar* line draw the line of Contingence as long as you can; then meaſure the ſhorteſt diſtance between the point of Interſection and the *Stilar line*, and transfer that diſtance on one ſide of the *line* of *Contingence* upon the *Subſtilar line*, and ſo deſcribe the *Equinoctial* Semi-circle againſt the *line* of *Contingence*: Then lay a ſtraight Ruler to the Center of the *Equinoctial Circle*, as at Æ, and to the point where the *line* of *Contingence* cuts the *Meridian Line*, as at Z, and mark where the ſtraight Ruler cuts the *Equinoctial Circle*, and from that mark begin to divide the *Semi-circle* into twelve equal parts, and by a ſtraight Ruler laid to thoſe diviſions and the center of the *Equinoctial*, make marks in the *line* of *Contingence*. Then ſhall ſtraight *lines* drawn from the Center A of the Dyal, through every one of the marks in the *Contingent line* be the Hour lines of the Dyal, and muſt be numbred from the XII a Clock line towards the right Hand, with I, II, III, IV, *&c.* And the other way with XI, X, IX, *&c.*

OPERAT. XI.

How to draw a Dyal *without a* Center, *on a* South Plane; Declining Eaſt 30 *Degrees*, Reclining 34 *Degrees* 32 Minutes.

HAving by the Precepts of *Operat.* IX. found the *Subſtile*, you muſt find the *Meridian line* otherwiſe than you were there taught: For, having drawn the *lines* of *Latitude*, *Declination* and *Reclination*, and found the *Subſtile*, meaſure the diſtance of B P, and ſet it off on the *line* of *Declination* from A to K, and draw from the Perpendicular A F the line K Q parallel to A B; then mea-

measure the length of K Q, and set it off on the *Polar line* A P, from A to V; then take the neareſt diſtance between the point V and the *line* A B, and ſet it off on the *line* Q K from Q to M; through which point M, draw a *line* from the Center A; then meaſure with your Compaſſes in the Semi-circle W N E (which in this Dyal may repreſent the Equinoctial) the diſtance of the Arch N *m*, and ſet off that diſtance from the Interſection of the *Subſtile* with the Semi-circle at S to T in the Semi-circle, which point T ſhall be the point in the *Equinoctial* that you muſt begin to divide the Hours at, for the finding their diſtances on the *line* of *Contingence*.



Then conſider (according to the bigneſs of your Plane) what height your *Stile* ſhall ſtand above the *Subſtile*, and there make a mark in the *Stile*; for the diſtance between the Center A and that mark muſt be

be the heighth of the *Stile* perpendicularly erected over the *Subſtile*, as at I. Draw through this point I a *line of Contingence*, as long as you can to cut the *Subſtile* at right *Angles*, and then laying a *Ruler* to the Center A, and ſucceſſively to each Diviſion of the *Equinoctial* make marks in the *line of Contingence*, and through thoſe marks draw ſtraight *lines* parallel to the *Subſtile*, which ſhall be the *Hour lines*; and muſt be numbred from the left hand towards the right, beginning at the XII a *Clock line* with I, II, III, *&c.* and from the right hand towards the left on the XII a *Clock line* with XI, X, IX, *&c.*

The *Stile* to this Dyal may be either a ſtraight Pin of the length of A I, or elſe a Square of the ſame heighth, erected perpendicularly upon the point I, in the *Subſtile line.*

OPERAT. XII.

To make a Dyal *on the* Cieling *of a* Room, *where the* Direct Beams *of the* Sun *never come.*

FInd ſome convenient place in the Tranſum of a Window to place a ſmall round piece of Looking-Glaſs, about the bigneſs of a Groat, or leſs, ſo as it may lie exactly Horizontal. The point in the middle of this Glaſs we will mark A, and for diſtinction-ſake call it *Nodus.* Through this *Nodus* you muſt draw a *Meridian line* on the Floor, thus: Hang a Plumb-line in the Window exactly over *Nodus*, and the Shadow that the Plumb-line caſts on the Floor juſt at Noon will be a *Meridian line*; or you may find a *Meridian line* otherwiſe by the Clinatory. Having drawn the *Meridian line* on the Floor, find a *Meridian line* on the Cieling, thus: Hold

a *Plumb-line* to the Cieling, over that end of the *Meridian line* next the Window; if the *Plumbet* hang not exactly on the *Meridian line* on the *Floor*, remove your hand on the *Cieling* one way or other, as you ſee cauſe, till it do hang quietly juſt over it, and at the point where the *Plumb-line* touches the *Cieling* make a mark, as at B; that mark B ſhall be directly over the *Meridian line* on the *Floor*: Then remove your *Plumb-line* to the other end of the *Meridian line* on the *Floor*, and find a point on the *Cieling* directly over it, as you did the former point, as at C, and through theſe two points B and C on the *Cieling*, ſtrain and ſtrike a *line* blackt with *Small-coal* or any other *Colour* (as Carpenters do) and that *line* B C on the *Cieling* ſhall be the *Meridian line*, as well as that on the Floor: Then faſten a ſtring juſt on the *Nodus*, and remove that ſtring, forwards or backwards, in the *Meridian line* on the *Cielling*, till it have the ſame Elevation in the *Quadrant* on the *Clinatory* above the *Horizon* that the *Equinoctial* hath in your Habitation, and through the point where the ſtring touches the *Meridian line* in the *Cieling*, ſhall a *line* be drawn at right *Angles* with the *Meridian*, to repreſent the *Equinoctial line*.

Thus in our Latitude the *Elevation* of the Equator being 38½ degrees; I remove the ſtring faſtned to the *Nodus* forwards or backwards in the *Meridian line* of the *Cieling*, till the *Plumb-line* of the *Quadrant* on the *Clinatory*, when one of the ſides are applied to the ſtring, falls upon 38½ degrees, and then I find it touc' he *Meridian line* at D in the *Cieling*; therefore at D I make a mark, and through this mark ſtrike the *line* D E (as before I did in the *Meridian line*) to cut the *Meridian line* at right Angles: This *line* ſhall be th. *Equinoctial line*, and ſerve to denote the Hour Diſtances, as the

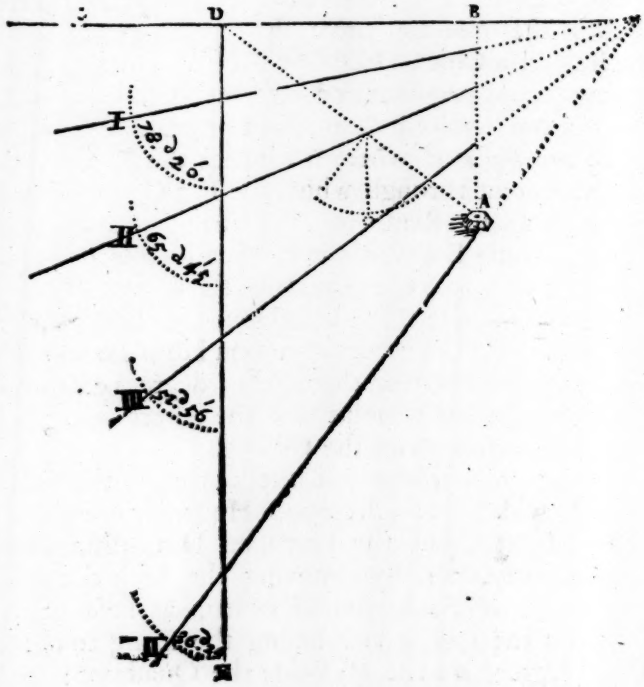
Contin-

Contingent Lines does on other Dyals, as you have often ſeen.

Then I place the Center of the *Quadrant* on the *Clinatory* upon *Nodus*, ſo as the Arch of the *Quadrant* may be on the *Eaſt* ſide the *Meridian* Line, and underprop it ſo, that the flat ſide of the *Quadrant* may lie parallel to the ſtring, when it is ſtrained between the *Nodus* and the *Equinoctial*, and alſo ſo as the ſtring may lie on the Semi-diameter of the *Quadrant*, when it is held up to the Meridian Line on the Cieling. Then removing the ſtring the ſpace of 15 degrees in the Quadrant, and extending it to the *Equator* on the Cieling, where the ſtring touches the *Equator*, there ſhall be a point through which the I a Clock Hour-line ſhall be drawn: and removing the ſtring yet 15 degrees further to the Eaſtwards in the Semi-Circle of Poſition, and extending it alſo to the *Equator*, where it touches the *Equator*, there ſhall be a point through which the II a Clock Hour-line ſhall be drawn. Removing the ſtring yet 15 degrees further, to the Eaſtwards in the Semi-circle of Poſition, and extending to the *Equator*, there ſhall be a point through which the III a Clock Hour-line ſhall be drawn: The like for all the other Afternoon Hour-lines. So oft as the ſtring is removed through 15 degrees on the Quadrant, ſo oft ſhall it point out the Afternoon diſtances in the Meridian line on the Cieling.

Having thus found out the points in the Equator through which the Afternoon Hour-lines are to be drawn, I may find the Forenoon Hour-diſtances alſo the ſame way, *viz.* by removing the Arch of the Quadrant to the *Weſt*-ſide the Meridian, as before it was placed on the *Eaſt*, and bringing the ſtring to the ſeveral 15 degrees on the *Weſt*-ſide the Quadrant; or elſe I need only meaſure the diſtances of each Hours di-

ſtance found in the Equator from the Meridian line on the Cieling; for the ſame number of Hours from XII, have the ſame diſtance in the Equinoctial line on the other ſide the Meridian, both before and after-noon: The XI a Clock Hour diſtance is the ſame from the Meridian Line, with the I a Clock diſtance on the other ſide the Meridian; the X a Clock diſtance, the ſame with the II a Clock diſtance; the IX with the III, *&c.* And thus the diſtances of all the Hour lines are found out on the Equator.



Now

Now if the Center of this Dyal lay within doors, you might draw lines from the Center through theſe pricks in the Equator, and thoſe lines ſhould be the Hour lines, as in other Dyals: But the Center of this Dyal lies without doors in the Air, and therefore not convenient for this purpoſe: So that for drawing the Hour lines, you muſt conſider what Angle every Hour line in an Horizontal Dyal makes with the Meridian; that is, at what diſtance in Degrees and Minutes the Hour lines of an Horizontal Dyal cut the Meridian; which you may examine, as by *Operat.* II. For an Angle equal to the Complement of the ſame Angle, muſt each reſpective Hour line with the Equator on the Cieling have.

Thus upon the point markt for each Hours diſtance in the Equinoctial Line on the Cieling, I deſcribe the Arches I, II, III, IV, as in the Figure, and finding the diſtance from the *Meridian* of the Hour Lines of an Horizontal Dyal to be according to *Operat.* II. Thus,

The	1	a Clock Hour Line.	11.40	whoſe *Complement* to 90 is	78.20
	2		24.15		65.45
	3		38.14		51.56
	4		53.36		36.24

I meaſure in a Quadrant of the ſame Radius with thoſe Arches already drawn from the Equinoctial Line,

for the	1	a Clock Hour	78.23
	2		65.45
	3		51.56
	4		36.24

and transfer the diſtances to the Arches drawn on the Cieling: For then ſtraight lines drawn through the

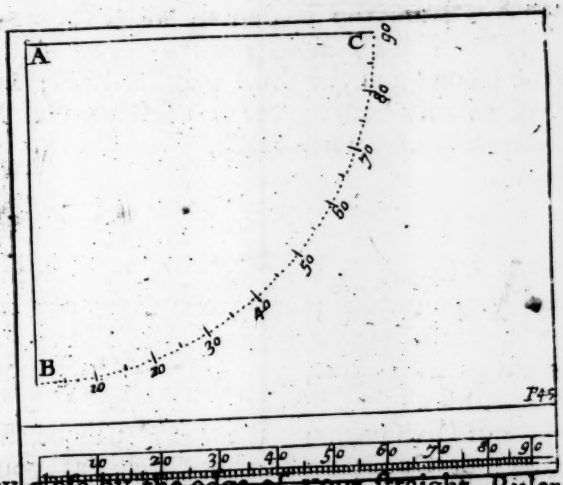
mark in the Arch, and through the mark in the Equator, and prolonged both ways to a convenient length, ſhall be the ſeveral Hours lines (aforeſaid;) and when the Sun Shines upon the Glaſs at *Nodus*; its Beams ſhall reflect upon the Hour of the Day.

Some Helps to a young Dyaliſt *for his more orderly and quick making of* Dyals.

IT may prove ſomewhat difficult to thoſe that are unpractiſed in Mathematical Projections, to divide a Circle into 360 Degrees (or which is all one) a Semicircle into 180, or a Quadrant into 90 Degrees; and though I have taught you in the projecting the *Horizontal Dyal* the original way of doing this, yet you may do it a ſpeedier way by a line of Chords, which if you will be curious in your Practiſe, you may make your ſelf; or if you account it not worth your while, you may buy it already made on Box or Braſs of moſt Mathematical Inſtrument Makers. This Inſtrument is by them called a *Plain Scale*, which does not only accommodate you with the diviſions of a Quadrant, but alſo ſerves for a Ruler to draw ſtraight lines with; the manner of making it is as follows.

Deſcribe upon a ſmooth flat even grain'd Board a quarter of an whole Circle, as B C, whoſe *Radius* A B or A C may be four Inches, if you intend to make large *Dyals*, or two Inches if ſmall; but if you will, you may have ſeveral lines of Chords on your *Scale* or *Rule*. Divide this Quadrant into 90 equal parts, as you were taught in the making the *Horizontal Dyal*.

Then



Then draw close by the edge of your ſtraight Ruler a line parallel to the edge, and at about $\frac{1}{10}$ part of an Inch a ſecond line parallel to that, and at about $\frac{1}{8}$ of an Inch a third line parallel to both. Then place one Foot of your Compaſſes at the beginning of the firſt degree on the Quadrant deſcribed on the Board, as at B, and open the other Foot to the end of the firſt degree, and transfer that diſtance upon your Rule, from B to the firſt mark or diviſion, between the two firſt drawn Lines. Then place one Foot of your Compaſſes again at the beginning of the firſt Degree on the Quadrant deſcribed on the Board, as at B, and open the other Foot to the end of the ſecond Degree, and tranſfer that diſtance upon your Rule from B to the ſecond mark or diviſion between the two firſt drawn Lines; and thus meaſure the diſtance of every Degree from the firſt Degree deſcribe on the Quadrant, and tranſfer it to the Rule. But for diſtinction ſake, you may draw every tenth diviſion from the firſt line parallel

to

to the edge of the third Line, and mark them in ſucceſſion from the beginning with 10, 20, 30, to 90: and the fifth Diviſions you may draw half way between the ſecond and the third parallel lines; the ſingle Diviſions only between the two firſt parallel Lines. So is your line of Chords made.

The uſe of the Line of Chords.

AS its uſe is very eaſie, ſo its convenience is very great; for placing one Foot of your Compaſſes at the firſt Diviſion on the Scale, and opening the other to the *60th* Degree, you may with the points of your Compaſſes (ſo extended) deſcribe a Circle, and the ſeveral Diviſions, on the *Scale* ſhall be the Degrees of the four Quadrants of that Circle, as you may try by working backwards, to what you were juſt now taught in the making the *Scale:* For as before you meaſured the diſtance of the Degrees of the Quadrant, and tranſferr'd them to the *Scale*, ſo now you only meaſure the Diviſions on the *Scale*, and transfer them to the Quadrant, Semi-circle, or whole Circle deſcribed on your Paper. For *Example.*

If you would meaſure 30 Degrees in your deſcribed Circle, place one Foot of your Compaſſes at the beginning of Diviſions on the *Scale*, as at A, and extend the other Foot to the Diviſions marked 30, and that diſtance transferred to the Circle, ſhall be the diſtance of 30 Degrees in that Circle. Do the like for any other number of Degrees.

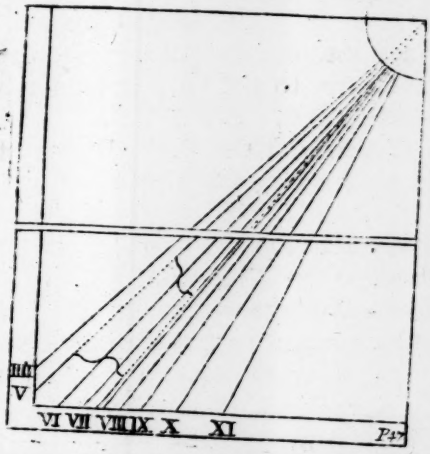
You may draw your Dyal firſt on a large ſheet of Paper, if your Dyal Plane be ſo large; if it be not ſo large, draw it on a ſmaller piece of Paper, Then rub the back-ſide of your Paper Dyal with ſmall Coal, till it

be

be well black't; and laying your Paper Dyal on your Dyal Plane, ſo that the Eaſt, Weſt, North, or South lines of your Paper agree exactly with the Eaſt, Weſt, North, or South ſcituation of your Dyal Plane; then with Wax or Pitch faſten the Corners of the Paper on the Plane, and laying a ſtraight Ruler on the Hour-lines of your Dyal, draw with the blunted point of a Needle by the ſide of the Ruler, and the Small-coal rub'd on the back ſide of the Paper will leave a mark of the lines on the Plane.

If you will have the Lines drawn Red, you may rub the back ſide of your Paper with *Vermillion*; if Blew, with *Verditer*; if Yellow with *Orpiment*, &c. Then draw upon theſe marked Lines with Oyl Colours, as you pleaſe.

If your Dyal Decline far towards the Eaſt or Weſt, the Hour Lines (unleſs projected to a very great length) will run very cloſe to one another; therefore in this caſe you muſt project your Dyal on a large Table, or ſometimes on the Floor of a Room, and cut it off as far as you think good, from the Center; for the further from the Center, the larger the diſtance of the Hour-lines. *See the Figure.*



An

An Explanation of ſome Words of Art uſed in this.

Angle. The meeting or joyning of two Lines.

Arch. A part of a Circle.

Axis. The ſtraight Line that runs through the Center of a Sphere, and both ways through the Circumference: though in *Dyalling* it is all one with the Diameter of a Circle.

Clinatory. See *Fol.* 8, 9, 10.

Chord. See *Fol.* 44, 45, 46.

Complement. The number that is wanting to make up another number 90 Degr. or 180 Degr. or 360 Degrees.

Contingent. A Line croſſing the Subſtile at right Angles.

Degree. See *Fol.* 12.

Diameter. The longeſt ſtraight Line that can be contained within a Circle, *viz.* the Line that paſſes through the Center to the Circumference both ways.

Dyal Plane. See *Fol.* 7.

Elevation of the *Pole.* So many Degrees as the *Pole* is elevated above the *Horizon.*

Equinoctial. The *Equinoctial* is a great Circle that runs evenly between the two *Poles* of the World. But when we name the *Equinoctial* in this Book, we mean a ſmall Circle which repreſents it, and is the Circle or Arch of a Circle which is divided into equal parts, to find thereby the unequal parts on the *Line of Contingence.* In the *Horizontal Dyal* it is that Arch of a Circle marked G C H.

Horizon. Is a great Circle encompaſſing the place we ſtand upon; but in Dyalling it is repreſented by a ſtraight Line, as in *Operat.* III. In the *South Dyal* the Line VI A VI is the *Horizontal Line.*

Latitude. The Latitude of a Place is the number of De-

Degrees contained between the *Equinoctial* and the place inquired after.

Line of *Contingence.* See *Contingent.*

Magnetick Needle. The Needle touch'd with the *Loadſtone*, to make it point to the North.

Meridian, is a great Circle of Heaven paſſing through the North and South points of the *Horizon*; but in Dyalling it is repreſented by a ſtraight *line*, as in *Operat.* II. in the *Horizontal Dyal* the *line* XII, A is a *Meridian line.*

Nadir. The point directly under our Feet.

Nautical Compaſs, Is the Compaſs uſed by *Navigators*, whereon is marked out all the 32 Winds or Points of the Compaſs.

Oblique Plane. See *Fol.* 7.

Parallel. See *Fol.* 6.

Perpendicular. See *Fol.* 5.

Pole. The North or South Points on the Globe of the Earth, are called *North* or *South Pole.*

Quadrant. The fourth part of a Circle.

Radius. Half the Diameter of a Circle.

Right Angle. A ſtraight *line* that falls perpendicularly upon another ſtraight line, makes at the meeting of thoſe two *lines* a Right Angle.

Semi-Circle. Half a Circle.

Semi-Diameter. The ſame *Radius* is.

Sphere. The higheſt Heaven with all its imagined Circles is called the *Sphere.*

Stile. The *Gnomon* or Cock of a Dyal.

Subſtile. The line the Stile ſtands on upon a Dyal Plane.

Triangle. A Figure conſiſting of 3 Sides and 3 Angles.

Zenith. The Point Directly over our Head.

F I N I S.

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